11. Environmental Radiation Monitoring

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Introduction

Many types of radioisotopes are used at LLNL, including transuranics, biomedical tracers, tritium, and mixed fission products for general research and nuclear weapons research. In accordance with federal regulations, DOE Orders 5400.1 and 5400.5, and Title 17, California Code of Regulations, Section 30250, LLNL monitors direct gamma radiation to establish background radiation levels in its vicinity and to determine the environmental radiological impact of its operations. Gamma radiation results from natural background sources of geologic/terrestrial or cosmic origin, or from man-made sources, such as fallout from past nuclear weapons testing and any contribution from LLNL operations.

Because environmental radiological monitoring is used as one measure of the potential direct radiation dose the public receives as the result of LLNL operations, LLNL has developed an extensive radiological monitoring network for its Livermore-site perimeter, the Livermore Valley, and the Site 300 perimeter. Both gamma and neutron radiation have been measured at the Livermore-site perimeter since 1973. A direct environmental radiation monitoring program was implemented at Site 300 in 1988. Gamma radiation is measured using thermoluminescent dosimeters (TLDs) that provide a measure of the total amount of gamma radiation at a particular location. Neutron radiation that may be generated from fusion facilities and particle accelerators is measured using modified Anderson-Braun rem meters.

Monitoring Locations

External doses from gamma radiation are monitored at 16 Livermore-site perimeter locations (as shown in **Figure 11-1**), and 48 Livermore Valley locations (**Figure 11-2**). These off-site locations are used for background comparison with perimeter locations. Similarly, there are 12 perimeter monitoring locations at Site 300 (**Figure 11-3**) and two locations in the nearby City of Tracy. Six additional locations, also shown in **Figure 11-3**, were added in 1993 in areas near Site 300 as a special study. Neutron monitoring locations were discontinued as of January 1, 1995, as discussed below.

Sitewide Network Assessment

In 1994, LLNL assessed the gamma and neutron radiation network, which led to redesign of the monitoring network. A study performed during the network assessment of trends in gamma radiation levels revealed seasonal variation at all sites from 1988–1994, as shown in **Figure 11-4**.

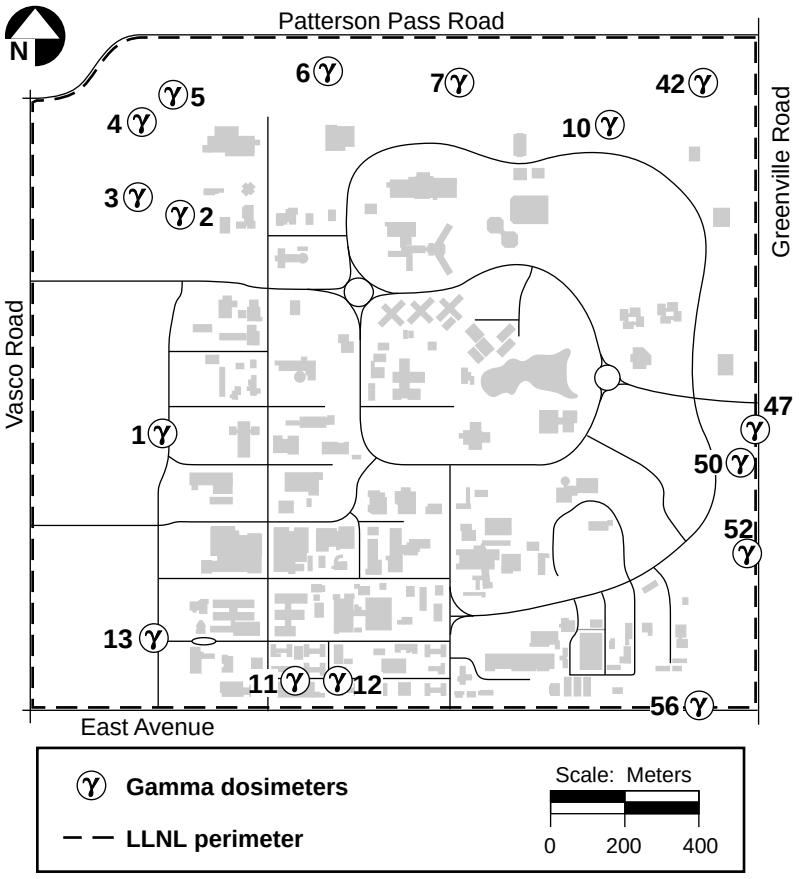

Figure 11-1. Gamma dosimeter locations, Livermore site, 1994.

Fall quarter gamma measurements show an increase of 0.03 to 0.08 mSv (3 to 8 mrem) when compared to the other seasons. These measurements increased at all sites at the same time in the fall of the year. The cause of this phenomenon is not yet known. Several researchers suggest that radon flux from the soil is elevated because of the lack of moisture following dry California summers when evaporation is high. During other seasons, water retards the emission of radon from the soil and serves as a shield for radon when the soil is moist. Variation in atmospheric mixing height may also contribute to seasonality in radiation measurements, resulting in high radon-in-air concentrations during periods of reduced mixing, particularly in the fall, preceding the rainy season. Variations in barometric pressure, inversion layers, and wind speeds from 1988–1993 and the daily average inversion height in the Livermore Valley all support a meteorological explanation for the observed seasonal variation (Fields et al. 1994). An investigation on seasonal variation will be conducted, and the results will be published in a subsequent report.

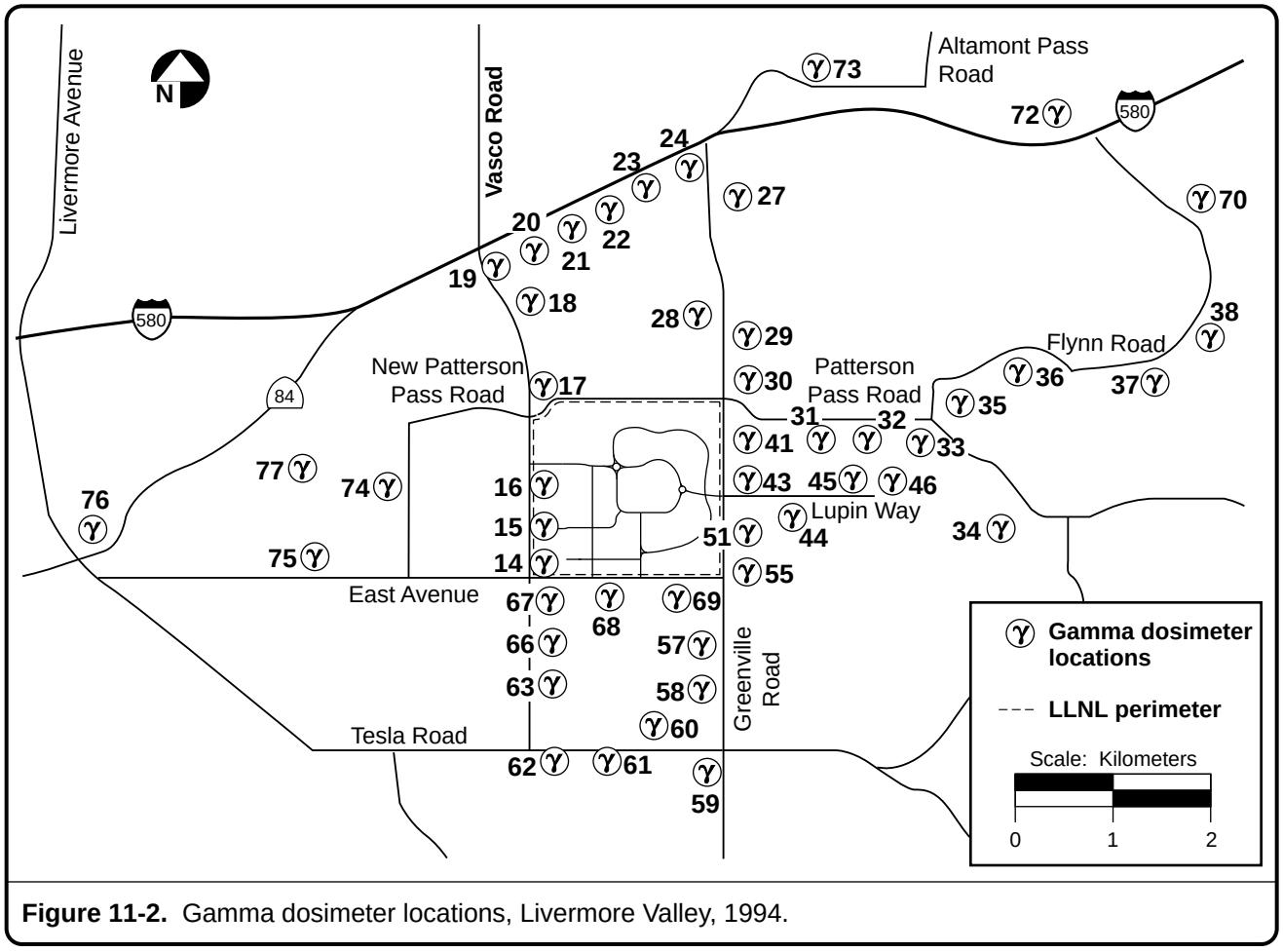

Figure 11-2. Gamma dosimeter locations, Livermore Valley, 1994.

The gamma data trending also demonstrated that large spatial correlation of monitors reduces the incremental information gained from multiple locations. Many locations showed redundancies in radiation measurements, and high spatial correlations occur at all sites. The standard deviation across all locations is less than 0.02 mSv (2 mrem) so that direct radiation effects across an entire area can be evaluated easily by a single TLD in that area. Therefore, the number of gamma ray monitoring locations to include all sites has been reduced from 78 to 52 as of January 1995.

In 1994, because the neutron rem meters had aged and deteriorated, the neutron measurements did not meet LLNL's accuracy and precision requirements. Therefore, the neutron data collected during 1994 are not reported herein, and neutron monitoring has been discontinued as of January 1995. Measurements of neutrons over the past decade showed background levels (approximately 0.044 mSv or 4.4 mrem per year), as has been reported in the Environmental Report from 1983 through 1993.

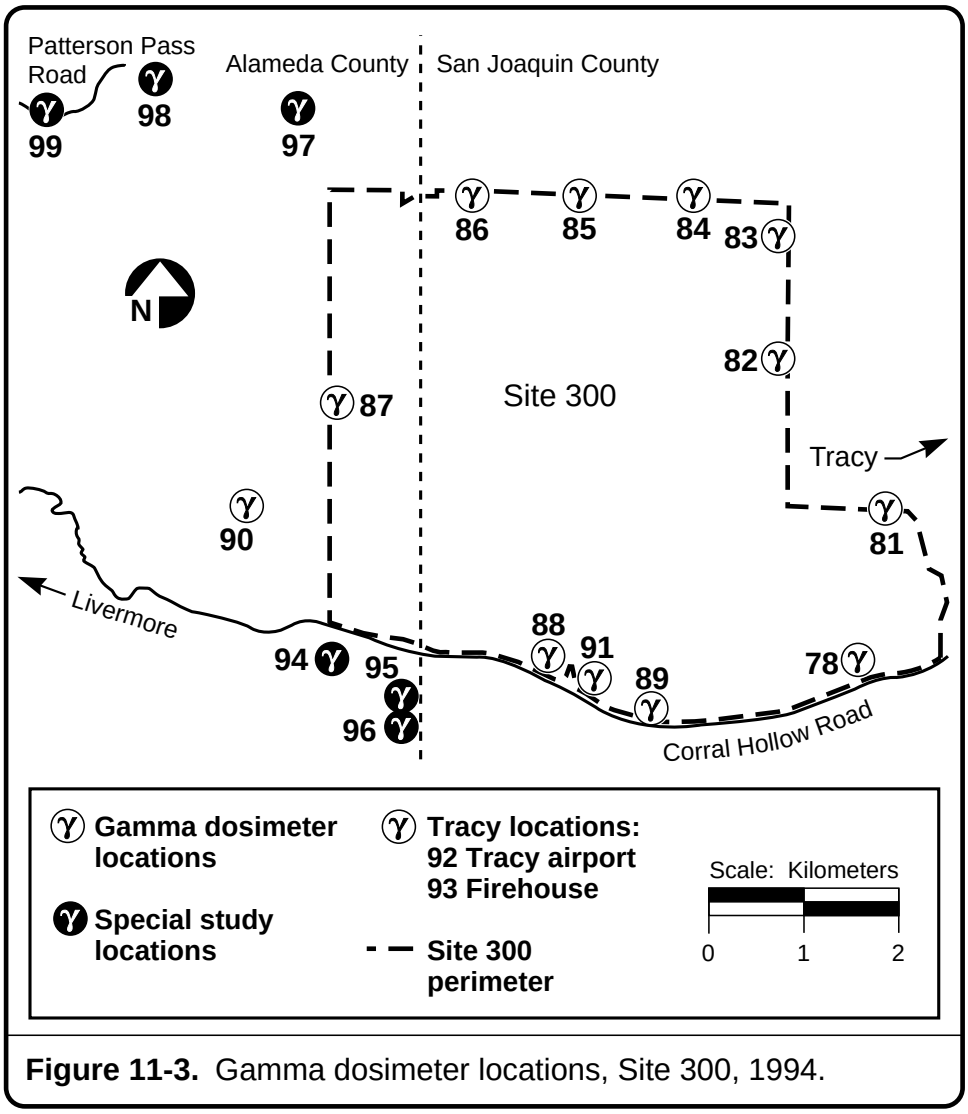

Figure 11-3. Gamma dosimeter locations, Site 300, 1994.

Results of Gamma Monitoring in 1994

Livermore Site

Table 11-1 presents a summary of the quarterly and annual TLD gamma radiation dose equivalents for the Livermore-site perimeter locations and Livermore Valley off-site locations. The median 1994 dose equivalent from external direct radiation exposure at the Livermore-site perimeter, 0.72 mSv (72 mrem), is about the same as background external dose measured in the Livermore Valley, 0.74 mSv (74 mrem). **Figure 11-5** presents the frequency distribution for external radiation dose measured at 48 Livermore Valley locations. See Chapter 11, Volume 2, of this report for a discussion of methods and more comprehensive presentation of the data.

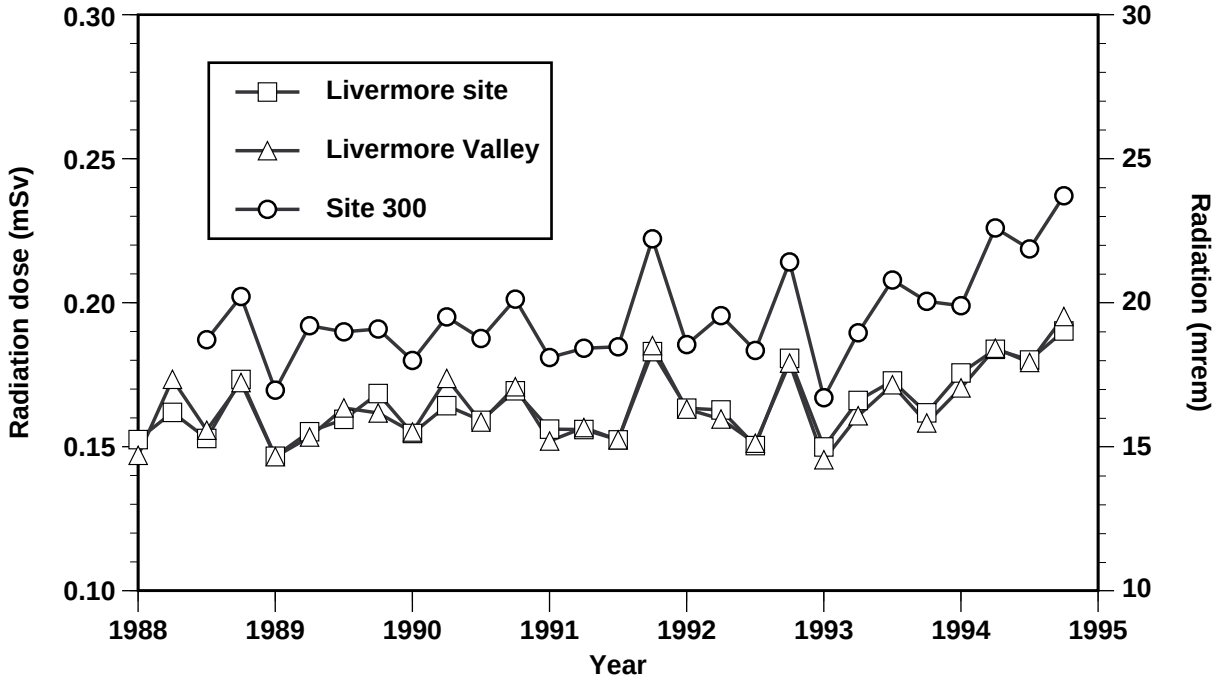

Figure 11-4. Gamma measurements at the Livermore-site perimeter, Livermore Valley, and Site 300 depicting quarterly seasonal variation, 1988 to 1994.

Site 300

Table 11-1 also presents the TLD data for routine monitoring at Site 300 during 1994, expressed as dose equivalent. The measured Site 300 perimeter average dose in 1994 was 0.88 mSv (88 mrem). The measured dose at off-site locations near Site 300 was this same value. The measured doses in and near Tracy were 0.66 and 0.77 mSv (66 and 77 mrem).

Environmental Impact

The 1994 direct radiation doses from all monitoring locations are slightly higher than the annual averages from previous years, as seen in **Table 11-3** and **Figure 11-4**. The cause of their increase is under investigation. Nevertheless, all doses are within the predicted range for background radiation, and no LLNL operational impacts are discernible.

Based on past measurements (Lindeken et al. 1973), environmental terrestrial (geologic) radiation doses in the Livermore Valley vary from 0.30 to 0.60 mSv / y (30 to 60 mrem / y). Cosmic radiation, as calculated for the local elevation and geomagnetic latitude according to the data of Lowder and Beck (1966), is about 0.35 mSv / y (35 mrem / y). This combination results in a typical total direct

Table 11-1. Summary statistics of all sites in mSv.

Location	Jan–Mar	Apr–Jun	Jul–Sep	Oct–Dec	Annual Total
Livermore-Site Perimeter					
Median	0.175	0.178	0.180	0.191	0.721
Interquartile range	0.019	0.025	0.021	0.015	0.086
Livermore Valley					
Median	0.171	0.183	0.180	0.194	0.735
Interquartile range	0.010	0.019	0.022	0.014	0.062
Site 300 Perimeter					
Median	0.199	0.226	0.217	0.237	0.876
Interquartile range	0.016	0.039	0.021	0.023	0.073
Tracy					
Median	0.171	0.182	0.174	0.195	0.721
Interquartile range	0.014	0.015	0.014	0.014	0.056
Site 300 Off-site					
Median	0.208	0.243	0.250	0.243	0.878
Interquartile range	0.020	0.051	0.015	0.019	0.162

Table 11-2. Annual dose by year due to direct gamma radiation at the Livermore-site perimeter.

Year	mSv	mrem
1987	0.64	64
1988	0.63	63
1989	0.63	63
1990	0.65	65
1991	0.65	65
1992	0.66	66
1993	0.65	65
1994[a]	0.74	74

[a] 1994 data is a median; previous values are means.

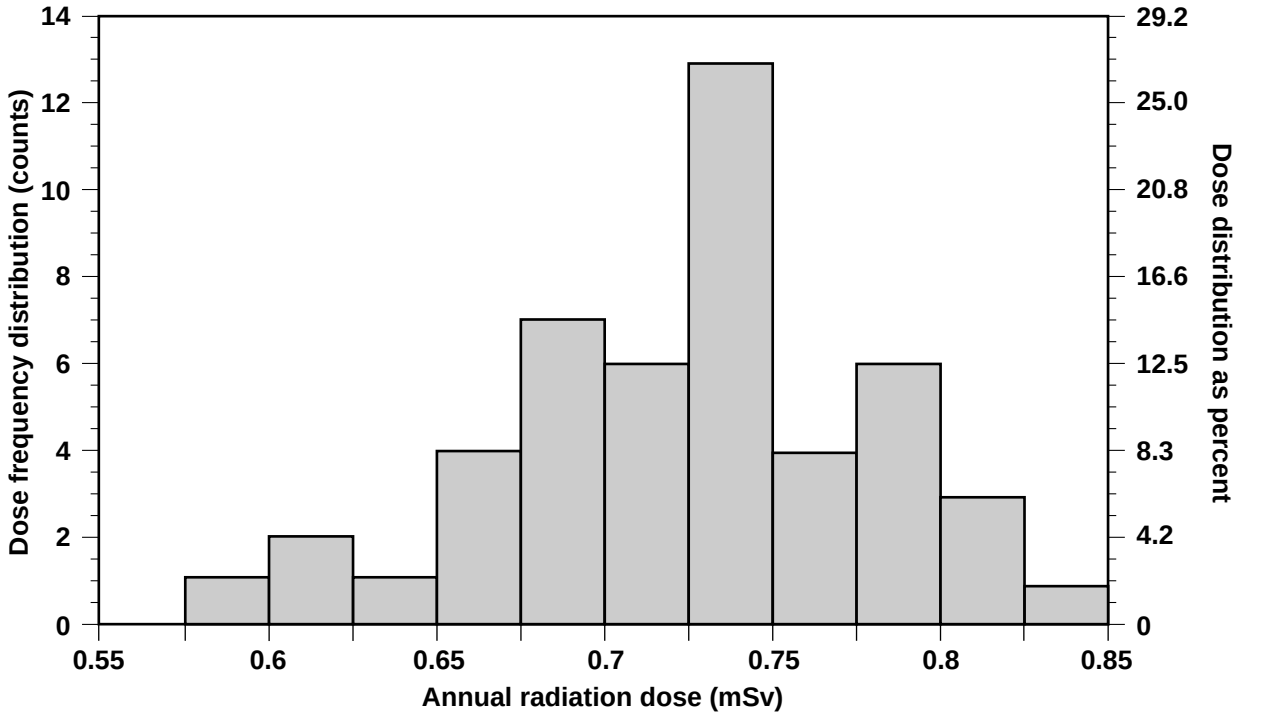

Figure 11-5. Annual direct gamma radiation dose, Livermore Valley, 1994.

radiation dose level of 0.65 to 0.95 mSv / y (65 to 95 mrem / y). Direct radiation doses measured at the Livermore-site perimeter in 1994 fall within these predicted values and are statistically equivalent to the Livermore Valley doses, which are considered natural background levels. This indicates that any dose from LLNL operations is not large enough to be seen within the wide range of natural variation in background levels in different locations.

At Site 300, the initial TLD network design limited monitoring to the Site 300 perimeter and two locations in and near the city of Tracy, which were chosen to represent background radiation levels. However, the Tracy locations are located on a geological substrate different from that at Site 300. The region around Site 300 has elevated levels of naturally occurring uranium, which is present in the Neroly Formation. The Tracy area, on the other hand, is at a lower elevation and the geological constituents are composed of alluvium deposits of clays, sands, and silts overlying the bedrock. As noted above, the 1994 average measured dose at the Site 300 perimeter was 0.88 mSv (88 mrem), which was identical to that from off-site locations near Site 300, while the average measured doses near the City of Tracy were 0.67 and 0.77 mSv (67 and 77 mrem), respectively. The difference in doses can be directly attributed to the difference in geologic substrates.